KM3NeT – The Next Generation Neutrino Telescope

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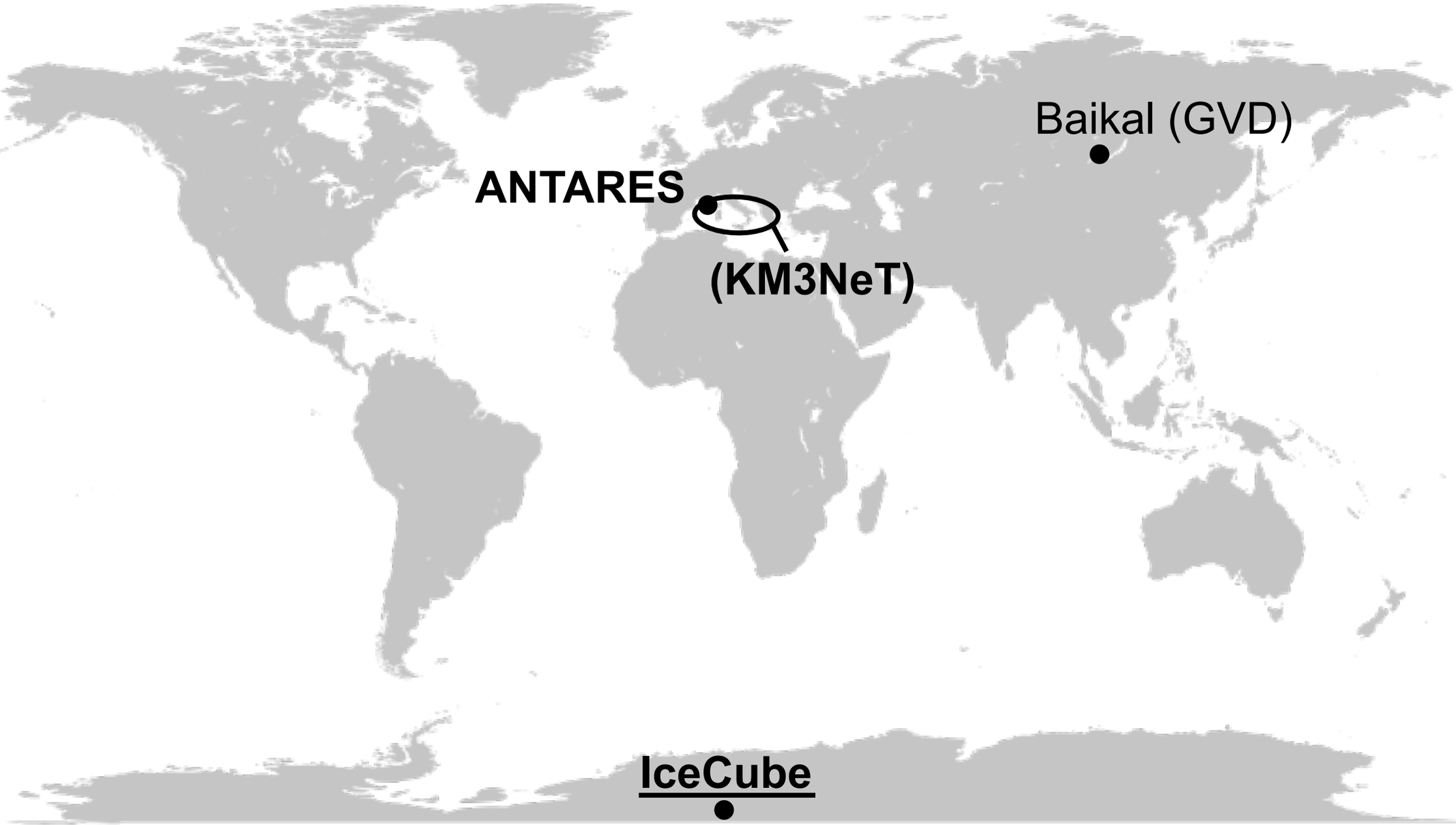
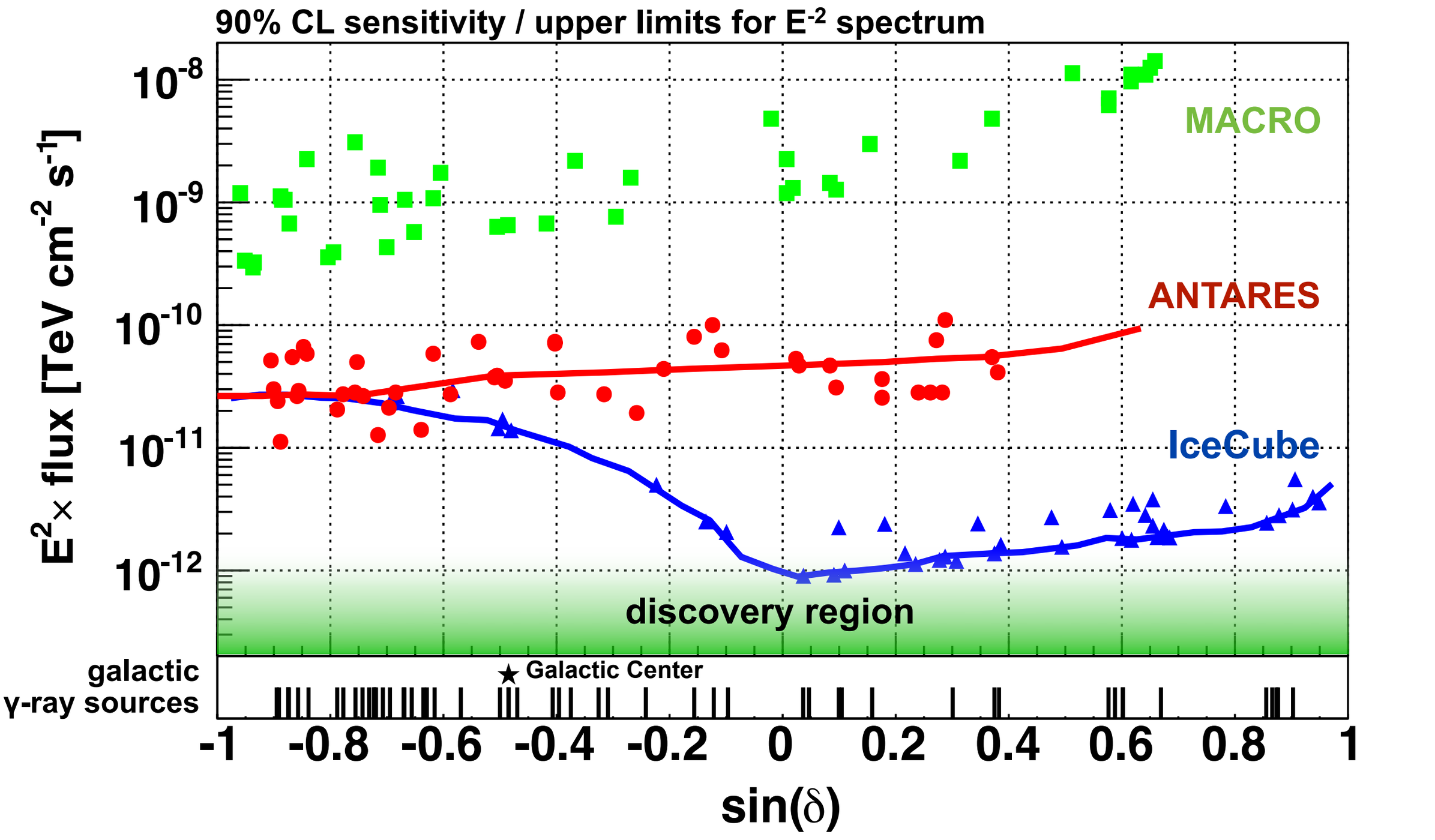
IceCube Particle Astrophysics Symposium
Union South, Madison, May 13, 2013

Current (planned) neutrino telescope projects

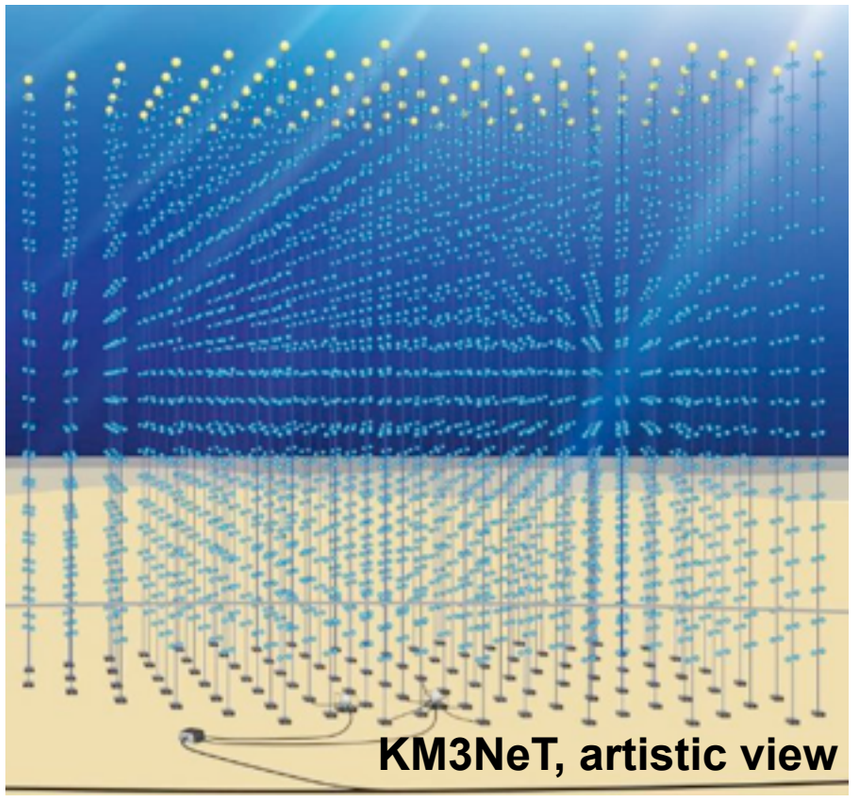


Current sensitivities to neutrino point sources



The KM3NeT research infrastructure

- Multi-km^3 neutrino telescope in Mediterranean Sea, exceeding IceCube substantially in sensitivity
- Central physics goals (by priority):
  - Galactic neutrino “point” sources (energy 1–100 TeV)
  - extragalactic sources
  - high-energy diffuse neutrino flux
- Decisions taken:
  - technology: strings with 18 multi-PMT optical modules
  - 6 building blocks of ~115 strings each
  - distributed-site installation (France, Greece, Italy)
  - central, remote operation and central data center


KM3NeT, artistic view

- Staged implementation: Phase-1 in progress, 40 M€ available
  (science potential from early stage of construction on)
- Overall investment ~220 M€ (operational costs 4–6 M€ per year)
- Nodes for deep-sea research of earth and sea sciences

The building block concept

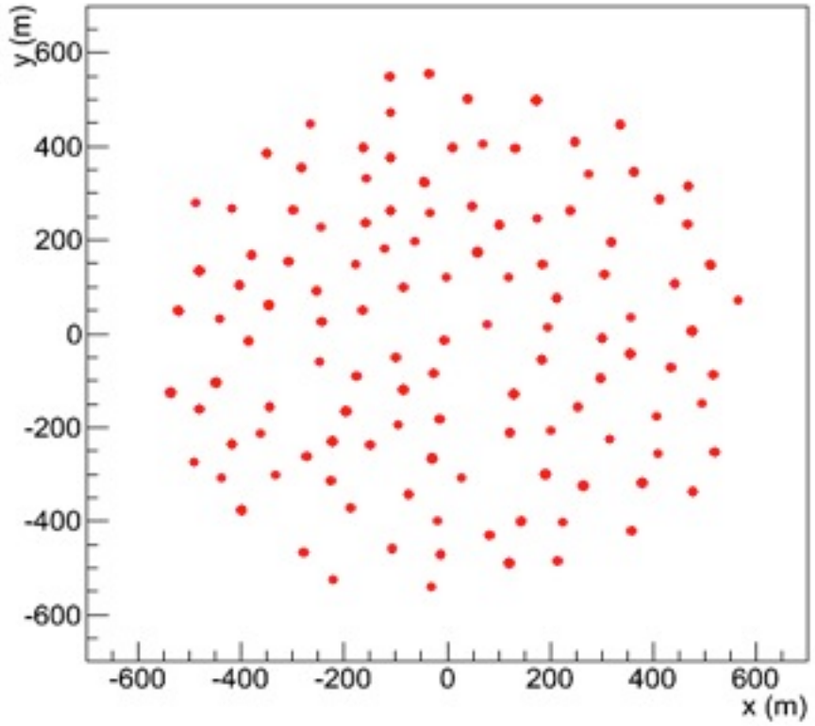
- Building block:
  - 115 detection units (DUs) ≈ one IceCube
  - segmentation enforced by technical reasons
  - sensitivity for muons independent of block size above ~75 strings

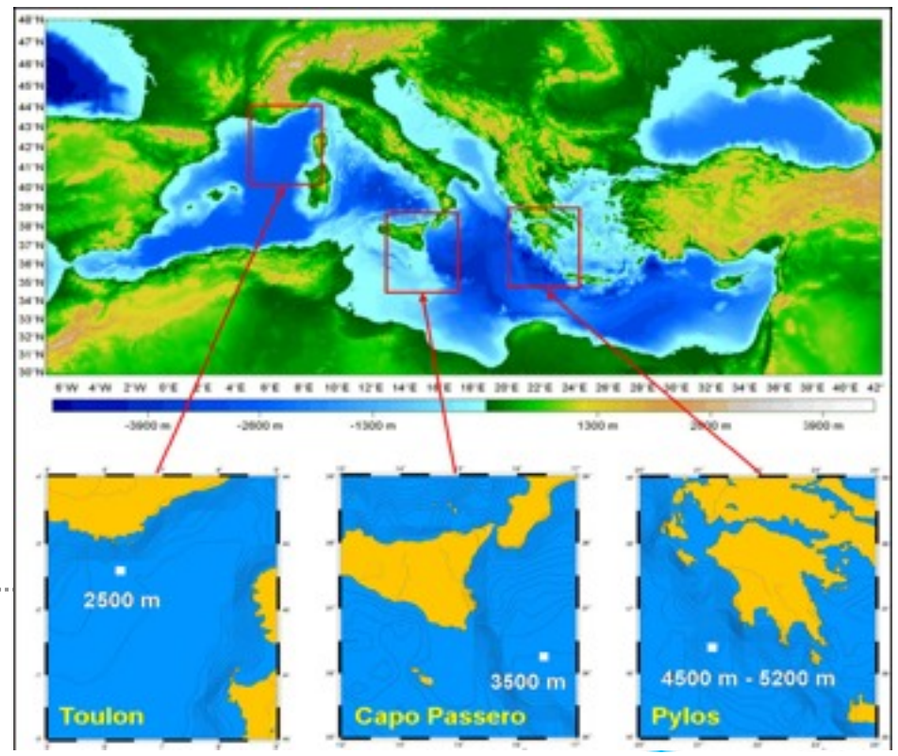
- Geometry parameters optimized for Galactic sources (*E* cut-off)

  → final optimization in progress

- Installation at location of pilot projects
  - KM3NeT−Fr: Toulon
  - KM3NeT−It: Capo Passero
  - KM3NeT−Gr: Pylos

Example configuration:
120 DUs, 100m aver. distance





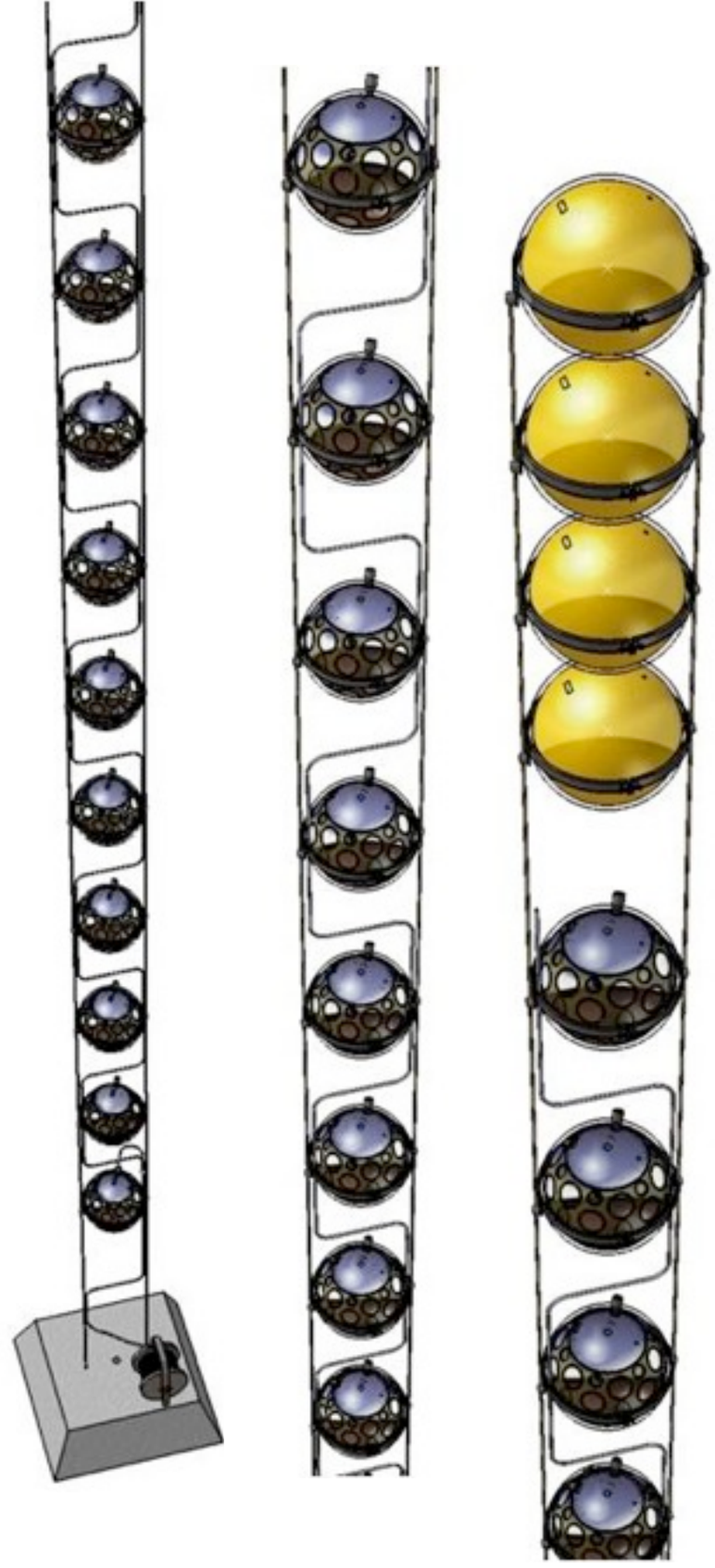
Detection units: Strings

Mooring line:

- Buoy (probably syntactic foam)
- 2 Dyneema© ropes (4 mm diameter)
- 18 stories (one OM each),
  30–36 m distance, 100 m anchor-first story

Electro-optical backbone (VEOC):

- Flexible oil-filled hose; ~ 6 mm diameter
- Fibers and copper wires
- At each story: connection to 1 fibre + 2 wires
- Break out box with fuses at each story:
  One single pressure transition



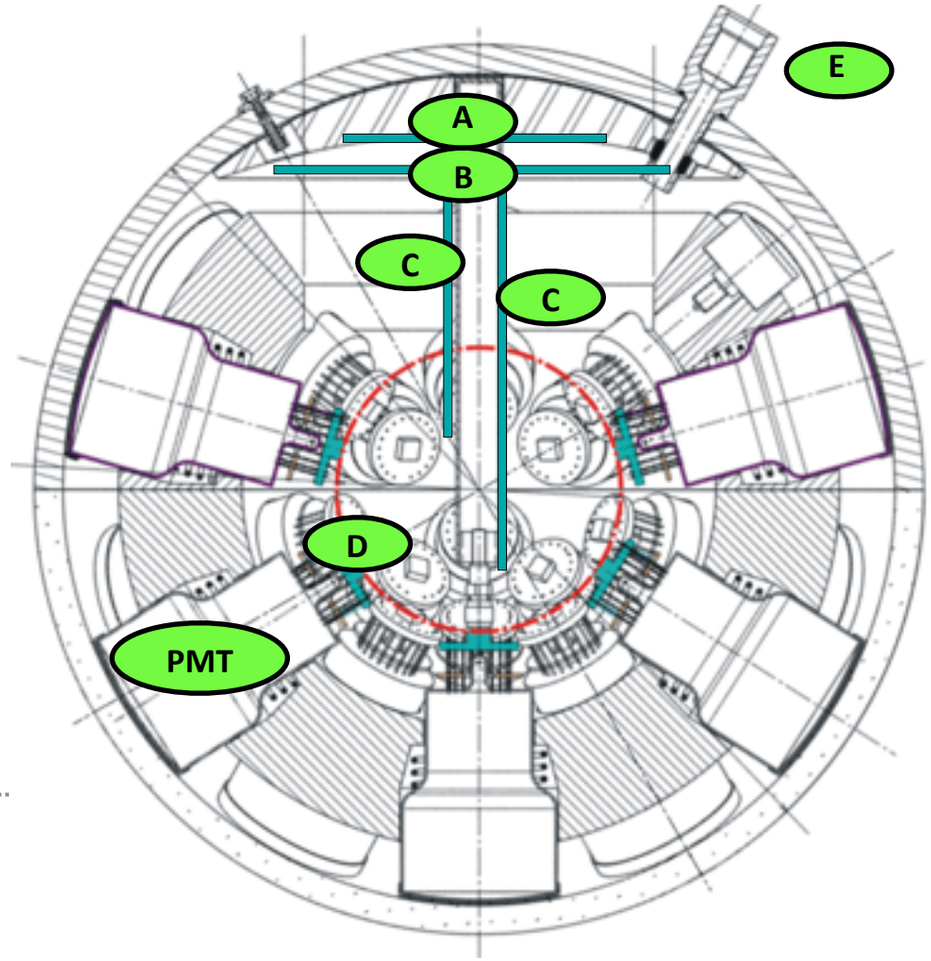
Optical modules with many small PMTs

Main features:

- 31 3-inch PMTs in 17-inch glass sphere (cathode area~ 3x10” PMTs)
  - 19 in lower, 12 in upper hemisphere
  - suspended by plastic structure
  - 2 mm optical gel
- 31 PMT bases (total ~140 mW) (D)
- Front-end electronics (B,C)
- Al cooling shield and stem (A)
- Single penetrator (E)

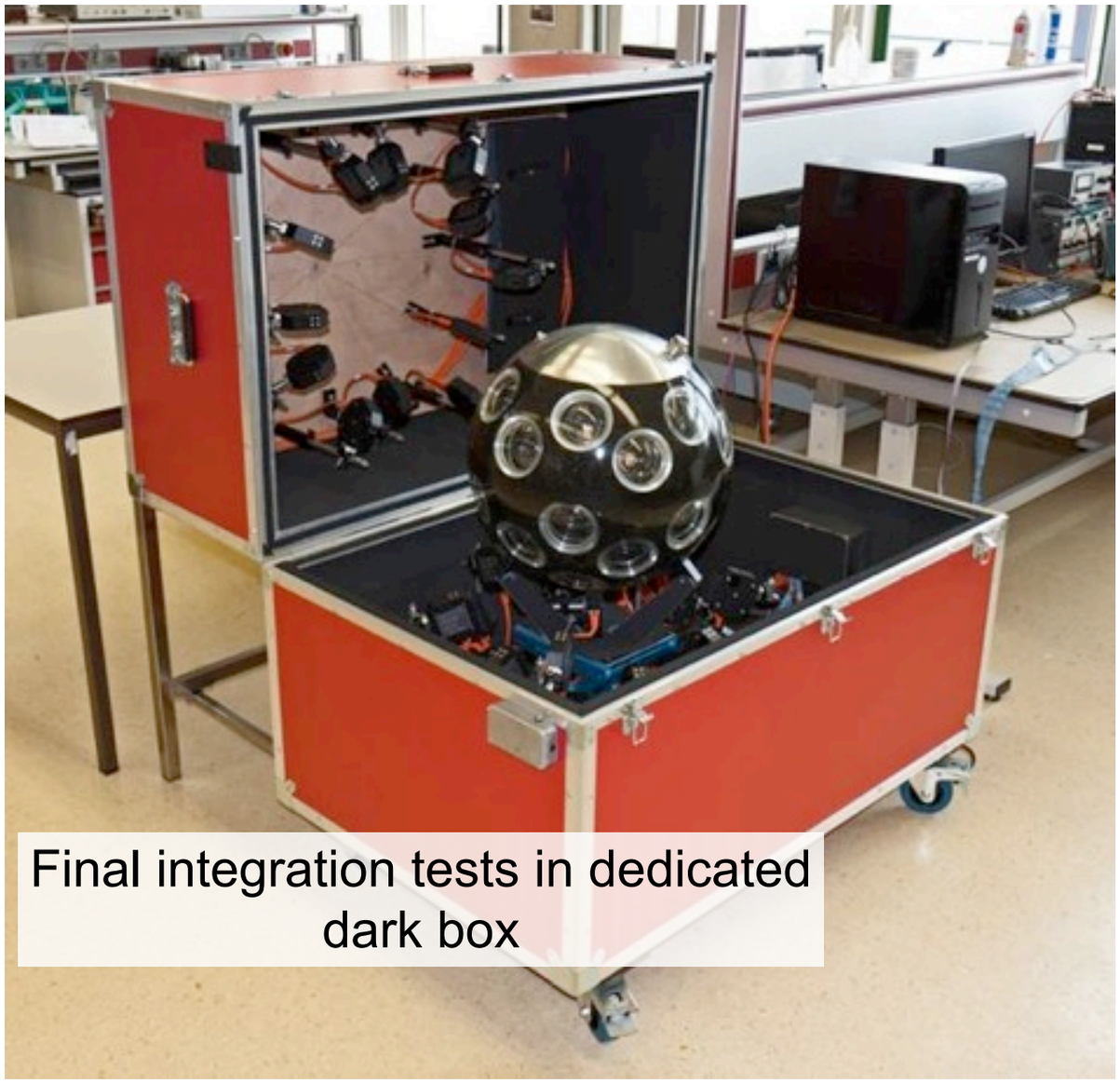
Advantages:

- Increased photocathode area
- 1-vs-2 photo-electron separation
  → better sensitivity to coincidences
- Directionality



The preproduction optical module (PPM-DOM)

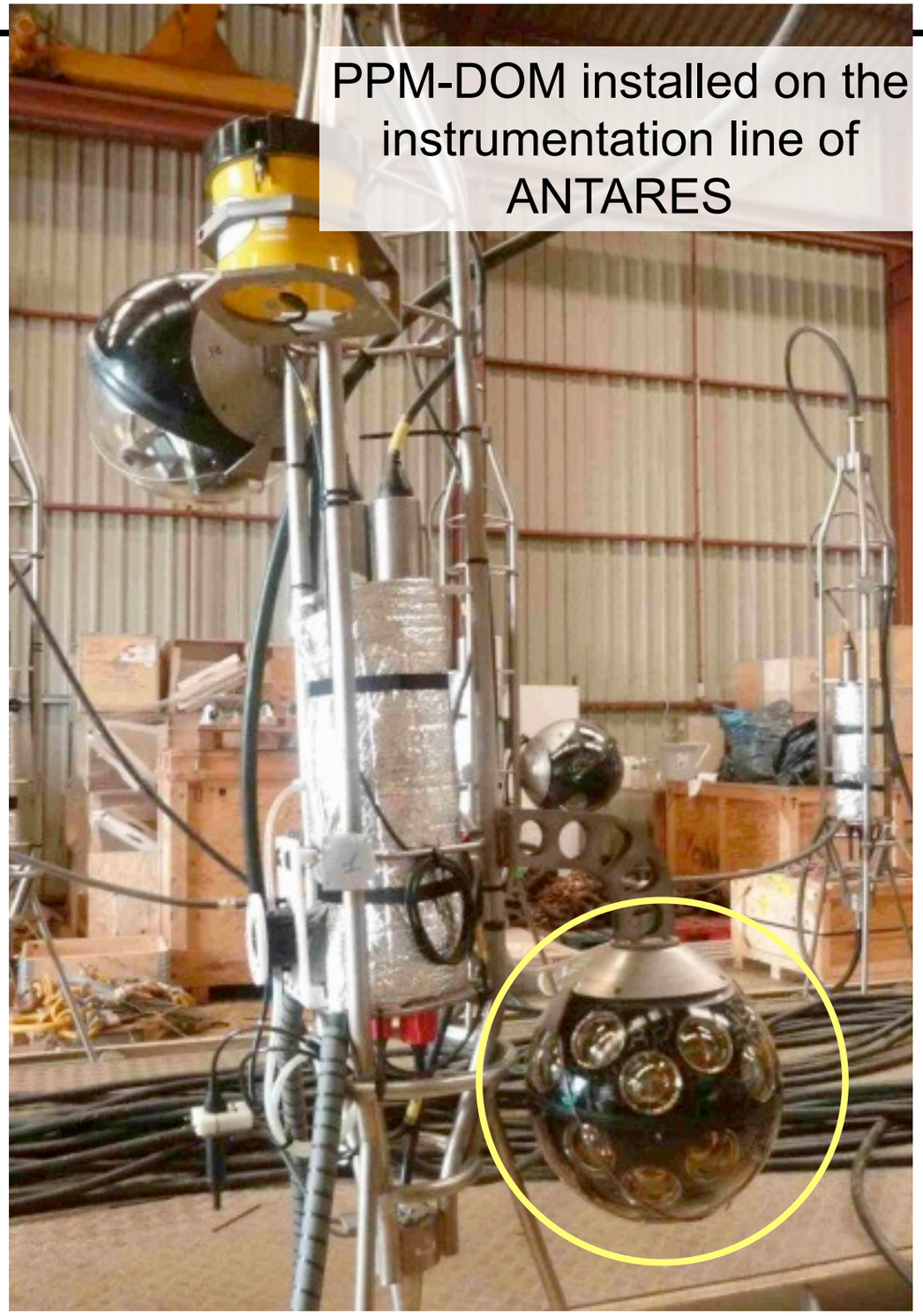
- Fully equipped DOM:
  - 31 PMTs
  - acoustic positioning sensors
  - time calibration LED beacon



Final integration tests in dedicated dark box

The preproduction optical module (PPM-DOM)

- Fully equipped DOM:
  - 31 PMTs
  - acoustic positioning sensors
  - time calibration LED beacon
- Mounted on the instrumentation line of ANTARES



PPM-DOM installed on the instrumentation line of ANTARES

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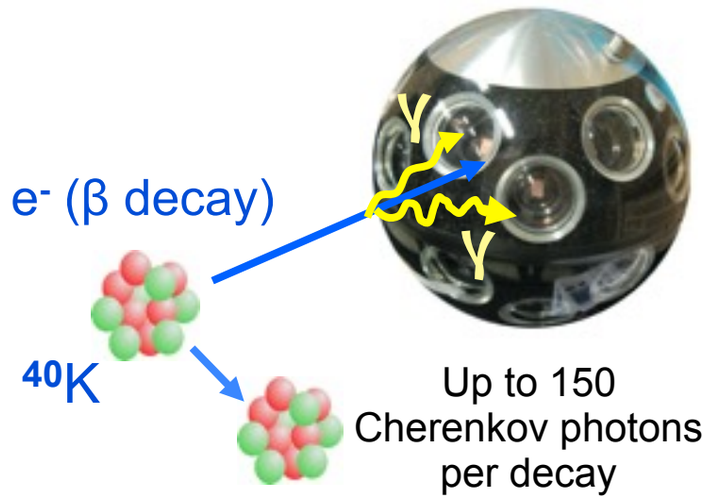
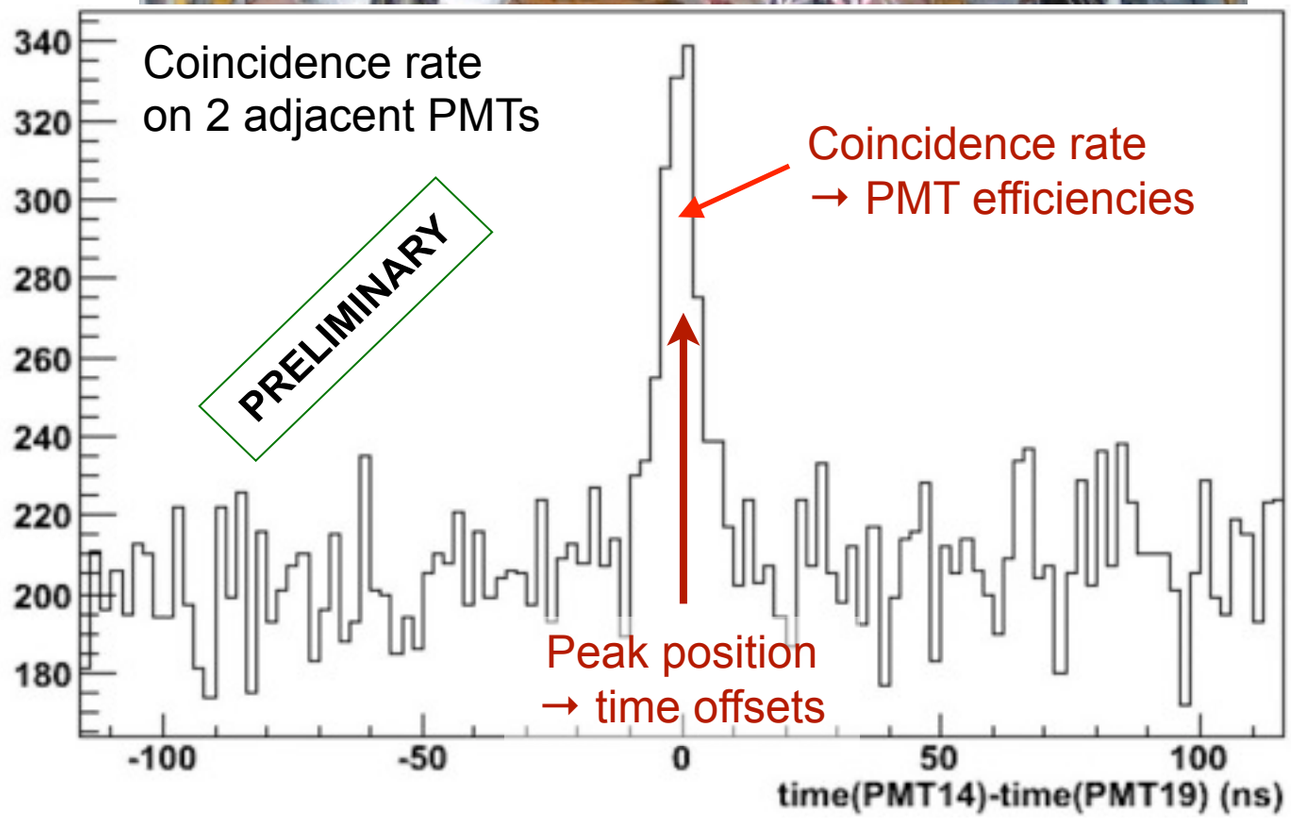
- Instrumentation line installed and connected on April 16, 2013

The preproduction optical module (PPM-DOM)

- Fully equipped DOM:
  - 31 PMTs
  - acoustic positioning sensors
  - time calibration LED beacon
- Mounted on the instrumentation line of ANTARES
- Instrumentation line installed and connected on April 16, 2013
- PPM-DOM fully operational and working correctly

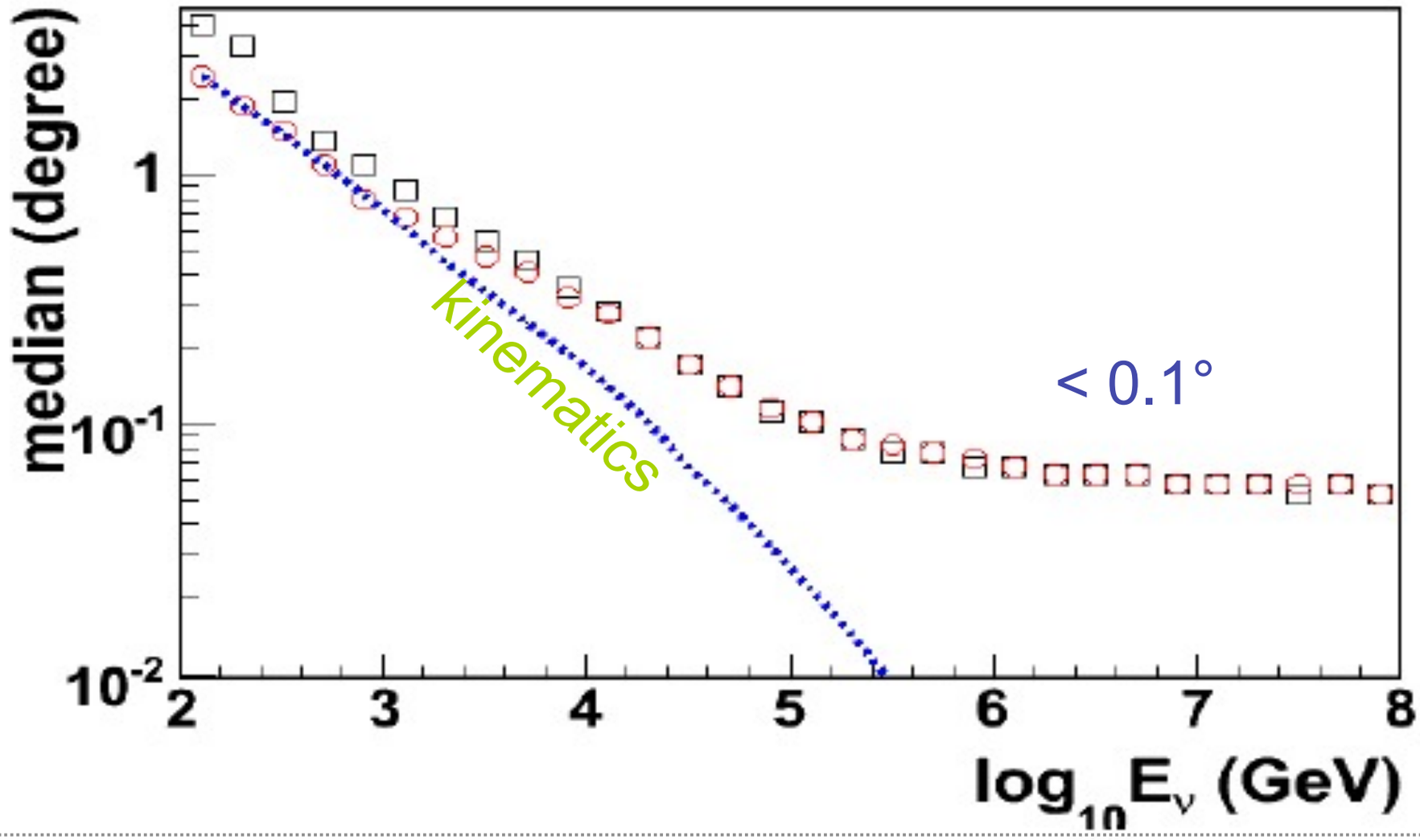




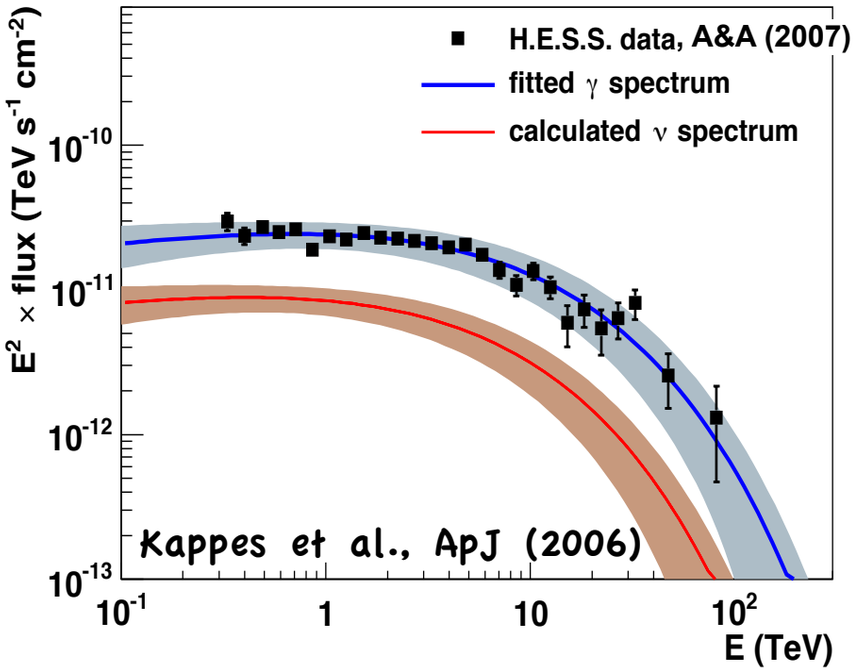
Physics prospects of KM3NeT

Angular resolution

- Angle between incoming neutrino and reconstructed muon
- Dominated by kinematics up to ~1TeV
- Energy resolution ~0.3 in log10(E_ν) for E_μ>1 TeV

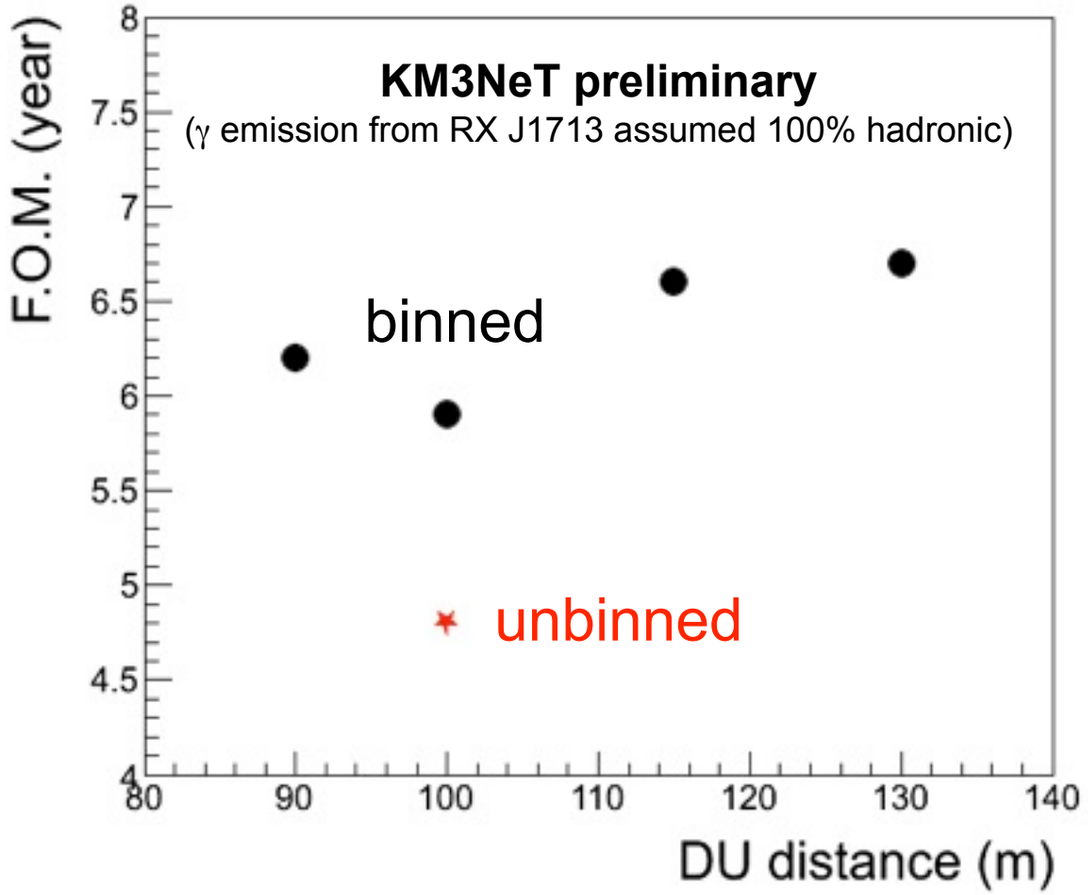


RX J1713: A prime candidate source



- Shell-type supernova remnant
- Compatible with proton acceleration in shock fronts (Fermi mechanism)
- Gamma spectrum measured by H.E.S.S.

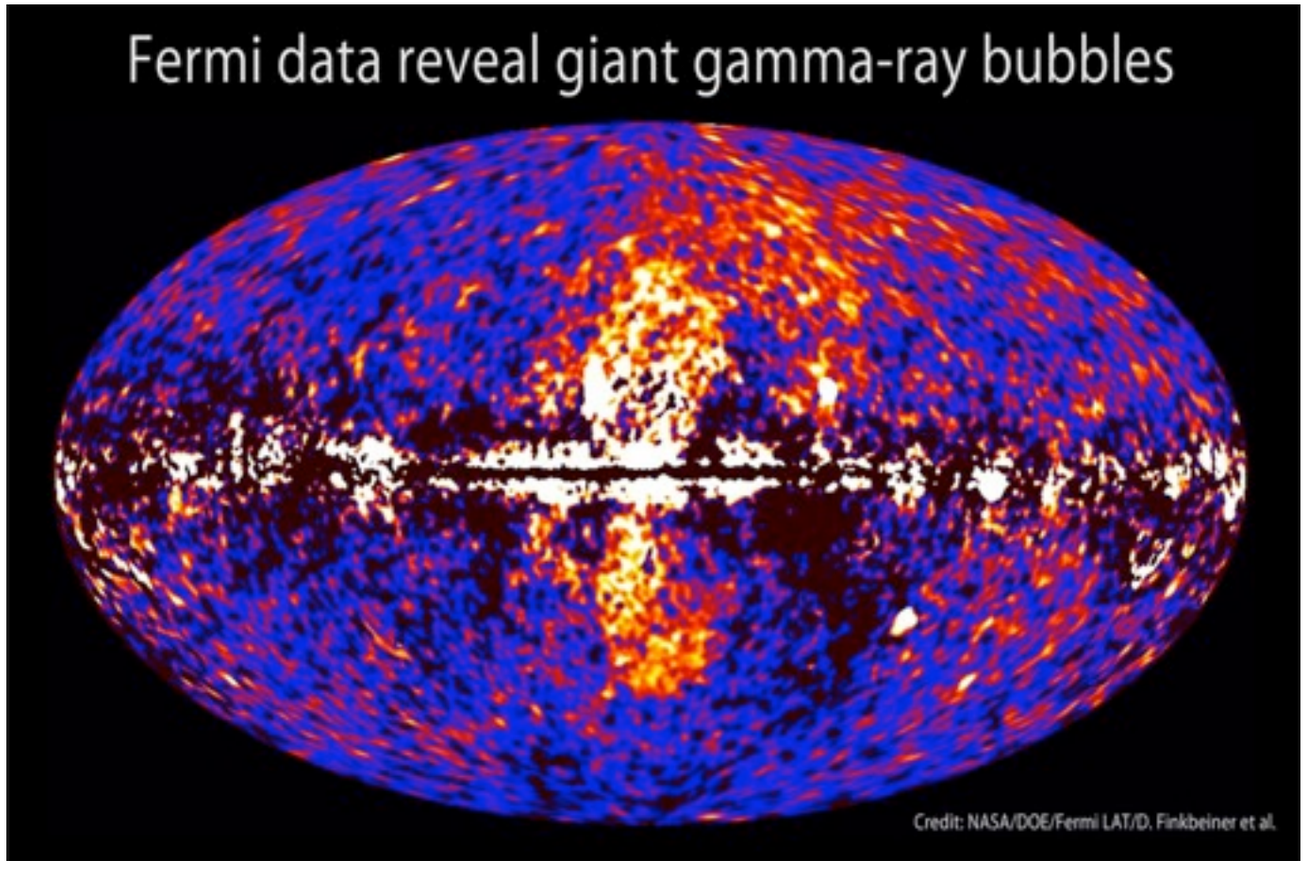
- Figure of merit (FOM): time for observation at 5σ with 50% probability
- KM3NeT analysis conservative:
  ~20% improvement by unbinned analysis
- Further candidate sources with good discovery chances
  (Vela X, Fermi Bubbles)



The Fermi bubbles

- Two extended regions above /below centre of Galactic plane
- Fermi detected hard γ emission (E^{-2}) up to 100 GeV
- Origin and acceleration mechanisms under debate

  if hadronic (Crocker, Aharonian, PRL (2011))
  → hot neutrino source candidate
- Could be first source detected by KM3NeT



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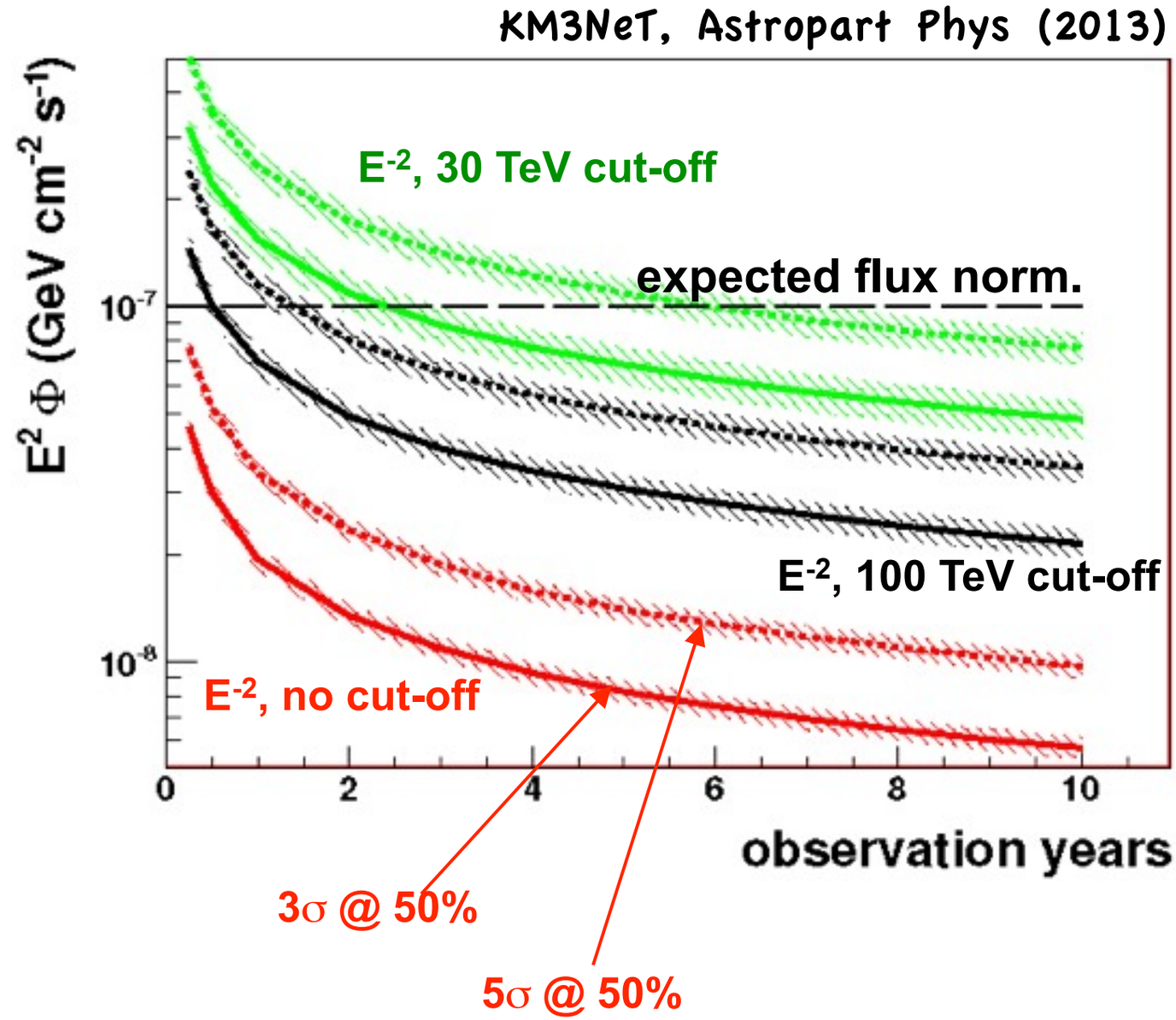

ORCA: A case study for KM3NeT

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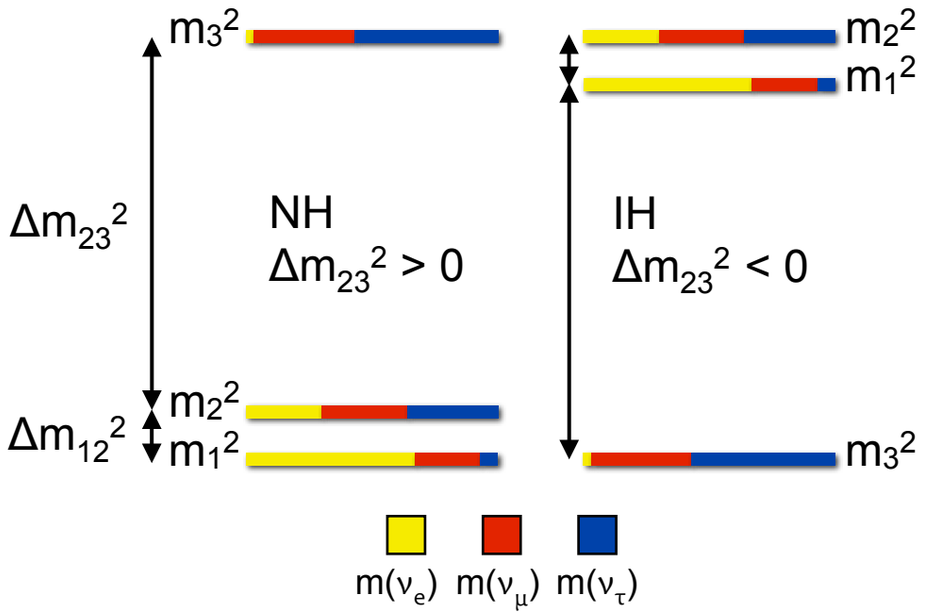
Akhmedov et al, arXiv:1205.7071:

Neutrino mass hierarchy might be measurable with neutrino telescopes via oscillation of atmospheric ν_μ (GeV) undergoing matter effects in Earth.



- Under study in KM3NeT Phase-1
- Many questions to be answered for a proposal
  - trigger/event selection efficiencies?
  - achievable resolutions on E_ν and θ ?
  - to what extend separation of different event classes?
  - how to control backgrounds?
  - dominant systematic effects and their control?
  - required calibration precision and how achievable?

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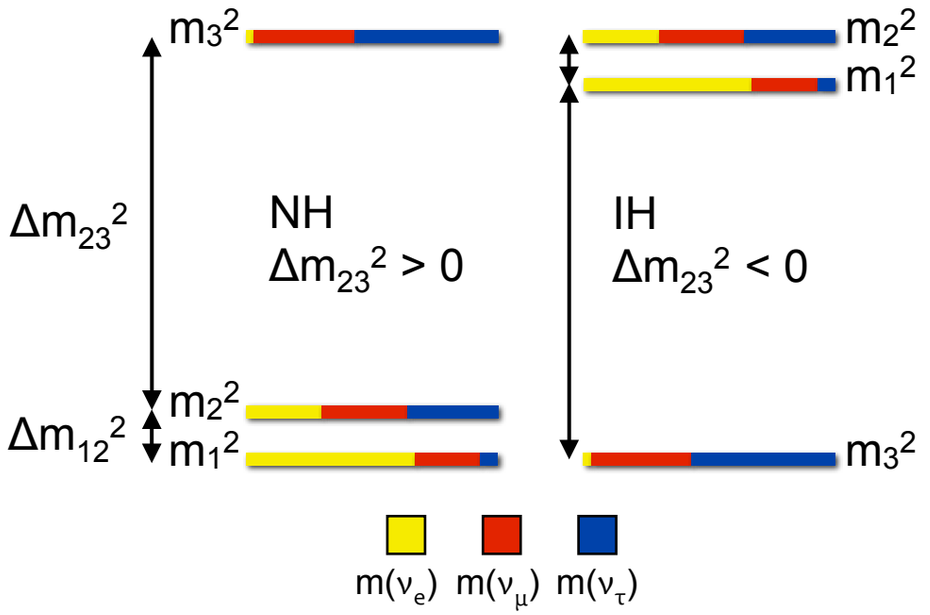

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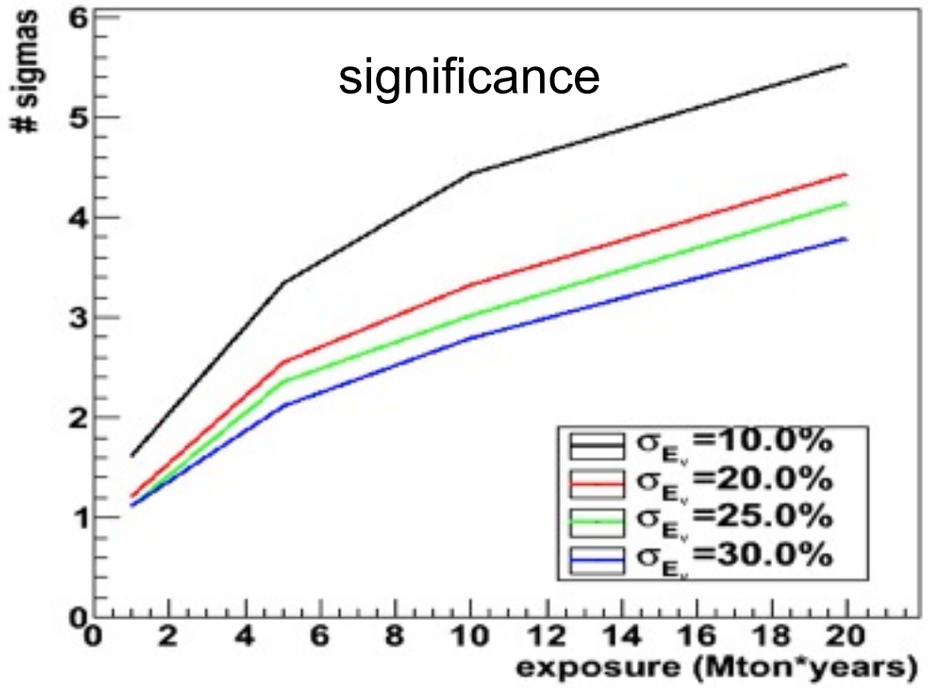
- Toy analysis
  - Experimental determination of mass hierarchy at 4–5σ level requires ~20 Mton-years



Summary

- ANTARES has demonstrated the feasibility of deep-sea neutrino telescopes
- KM3NeT will provide a multi-km^3 installation in the Mediterranean Sea sensitive enough to detect Galactic sources and more
- The design process has concluded in an agreed technology (strings with multi-PMT digital optical modules)
- KM3NeT will be a distributed (France, Greece, Italy), centrally operated observatory
- It will provide nodes for earth/sea sciences
- The first construction phase is underway
- A low-energy option (ORCA) is under investigation